Request for Economic Stimulus Funds

<u>Concept</u> <u>Proposal</u>

1. Submitters (Name of Workgroup & Chair/Co-Chairs):

Energy and Sustainability Group (Dr. Doug Whitlock and Dr. James Tracy)

2. Project Title:

Carbon-Managing and Upgrading of Aged Utility Plants Using Coals

3. Project Partners (Known or Anticipated):

Western Kentucky University and EnCana Corporation

4. Project Background & Purpose (Justification for Project):

Under President Obama's economic stimulus plan, carbon managements will be the priority in fossil-fuel energy utilization. Existing coal-fired power plants are likely targets for future climate change regulations to reduce CO_2 emissions. Consequently, Kentucky with large coal reserves and productions will have to deal with these new carbon management regulations. In 2008, the U. S. DOE canceled plans for building FutureGen in Illinois, which would incorporate carbon capture and storage (CCS), after the plant's estimated capital cost rose to 1.8 billion. U. S. DOE, working with EPA, may prefer the demonstration of 50% CO_2 capture in existing coal-fired power plants.

The capacity of coal-fired electricity generating is forecast to increase to nearly 450 GW by 2030. However, only about 6 GW of the existing coal-fired electricity generating fleet is projected to retire. The coal-fired electric power sector emits a sizable amount of CO_2 according to EIA data. It is very likely that existing coal-fired power plants will be a future target of climate change regulations. Obviously, Kentucky that has large coal reserves and productions will be impacted by these future carbon management regulations.

In conventional combustion systems, the capture of CO_2 with low partial pressure will result in significant energy penalty. Roughly one-fifth of the electricity produced will be lost to CO_2 separation and compression. Thus, the estimated cost of the CO_2 separation at $100-150 per ton of carbon with currently available technologies is much higher than its sequestration cost ($4-8 per ton of carbon). Advanced oxy-firing combustion will face the challenges of expensive oxygen production, flue gas re-circulation and the enhancement of heat transfer. Among all available proposed technologies on carbon management, CLC is a novel process using oxygen carriers to indirectly combust fossil fuels with simultaneous production of high concentration of CO_2 without energy penalty and enhanced combustion efficiency. Less NO_x emission is expected due to its flame-less combustion properties. Emissions control of other major air pollutants in CLC process is generally more cost effective than conventional post combustion treatment, because of higher concentrations of air pollutants in and lower mass flow rate of its flue gases. However, starting from the introduction of CLC in 1983, solid fuels, such as coal and biomass, have not been used in CLC due to very slow solid-solid reaction kinetics. Benefits of development of coal-based CLC technologies are significant to Kentucky to sustain the long-term economical, efficient and environmentally responsible utilization of rich coal resource in existing coal-fired power plants.

Institute for Combustion Science and Environmental Technology (ICSET) of Western Kentucky University (WKU) is first in the United States to explore the likelihood of applying CLC concept using solid-fuels sponsored by the DOE-SBIR program. Tests indicated the complete conversion of coal chars with acceptable kinetics was challenging. In this project, we proposed not to use coal in a single step. Instead we propose a novel approach, namely, the active carbon constituents in raw coal will be pyrolyzed, partial gasified and combusted inside the chemical looping process to produce concentrated CO_2. In this step, fast kinetics of coal pyrolysis and partial gasification will replace full gasification of coal with ultra-high temperatures. The produced char residue in the our novel approach, which is less reactive in chemical looping process, will then be directly combusted in the existing pulverized coal boilers (PCB) that have elevated reactivity. In this integrated process, CLC plus PCB, the varied kinetics of raw coal during gasification and conversion is well organized into different combustion technologies under request for CO_2 concentration. Therefore, our goal of applying coal-fired CLC process will be the development of a coal partial gasification chemical looping module (CPGCLM), as well as its adaptability to the existing coal-fired power plants. It will allow for upgrading and repowering of aged units with efficiency enhancement and capacity enlargement. The potential impact of this project is the realization of affordable CO_2 separation technology that can be introduced into the existing coal-fired power generation fleet, based on sound scientific and engineering understandings of coal combustion and gasification.

5. Project Description (General Goals & Implementation Strategies):

The objectives of the proposed project will be to rationally optimize the recovery of coal energy using different conversion technologies, as well as to utilize the unique properties of CLC for concentration of CO_2 without energy penalty. Attrition-resisting and thermally stable oxygen carriers will be developed to achieve auto-thermal heat balance of the processes, generate a high purity CO_2 and favorable kinetics and free-oxygen releasing. Chlorine and sulfur tolerances of prepared oxygen carriers will be addressed. A separation technique for coal char residues from the oxygen carrier is identified. The possibilities for multiple control of major air pollutants (SO_2, NO_x, and Hg) will be addressed.

The proposed project will include: 1) To investigate optimization of coal-based energy utilization using the unique properties of the chemical looping cycle to concentrate CO_2; 2) To investigate technical approaches for fitting the proposed technology into coal-fired boilers, including circulating fluidized bed boilers and pulverized coal boilers; 3) To develop technically-sound oxygen carriers for chemical looping cycle with characteristics of auto-thermal heat balance of the process, high purity of CO_2, favorable kinetics, attrition-resistance, and thermal stability; 4) To establish a theoretical frame of reaction enthalpy, chemical equilibrium and chemical reaction kinetics of selected oxygen carriers; 5) To investigate the transformations of major air pollutants (SO_2, NO_x and Hg) during the proposed combustion processes and their multiple control technologies efficiently; 6) In a cold-model facility, several technical issues will be investigated and solved, including the separation of the oxygen carrier from char residues, the prevention of the possible interaction between the char residues and oxygen carriers, and the gas leakage between oxidizer and reducer; 7) To setup a lab-scale coal-based CLC facility, in which a 8-hour continuous test will be pursued. The investigation of the prevention of gas leakage and the separation of oxygen carrier and char residues in this hot-model facility will also be pursued; 8) To solve technical issues, system integration and obtain design parameters on this novel concept using a Circulating Fluidized Bed (CFB) system and a moving bed based.

In a 24-month time frame, the development of the oxygen carriers, investigation of cold-model hydrodynamics, and a subsequent integrated hot-model bench-scale test will be conducted to achieve the project goal. A 0.6 MW CFB system, which is available after proper modification at the ICSET of WKU, will be used for future technology demonstration. ICSET's long-term and extensive involvement in the development of novel coal-based processes and its previous experiences in the development of CLC processes using solid fuels, sponsored by U.S. DOE, are solid bases for success of the proposed project. The proposed hybrid CPGCLM technology is expected to fit in the segment of coal-fired boilers after this project. They could also be scaled-up into full CLC technology, eventually replacing the existing conventional coal-fired combustion processes with enhanced combustion efficiency. This proposed flexible hybrid cycle platform will allow this evolution to occur with intermediate steps along the way. Its market prospects are strong since the building block of CLC is the commercially available circulating fluidized bed boiler (CFB).

6. Project Team (Project Manager(s), Content Experts, Instructional Designers, etc.):

Dr. Wei-Ping Pan (Energy Balance), Director of ICSET; Dr. Yan Cao (Engineering Design), Assistant Director of ICSET; Dr. Song Sit (Chemical Reaction), Technical Advisor of EnCana Corporation

7. Project Budget & Amount of Economic Stimulus Funds Requested:

ICSET will contribute available facilities, instrument and lab space as primary sources to develop the proposed project, except a few facilities which need to be newly setup. Major funding will be used to support high-quality team to conduct research and development on the proposed concept and process integration. In Year 1, the estimated cost is $800,000 which including (1) Team's salaries and fringes: PI, CO-PI, research Associates, Technicians and Specialists; totally 12 persons; (2) Newly setup facilities include chemical looping oxidizer and reducer (3) Materials for proposed tests (gas and chemicals). In Year 2, the estimated cost is $700,000 for process integration and demonstration. The total cost of this project is **$1,500,000**.